Semi-inclusive Deep Inelastic Scattering at HERMES and at the proposed EIC

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- HERMES 5 flavor decomposition
- HERMES Isoscaler Δs extraction
- HERMES Future Plans
- EIC Projections

Purity Analysis

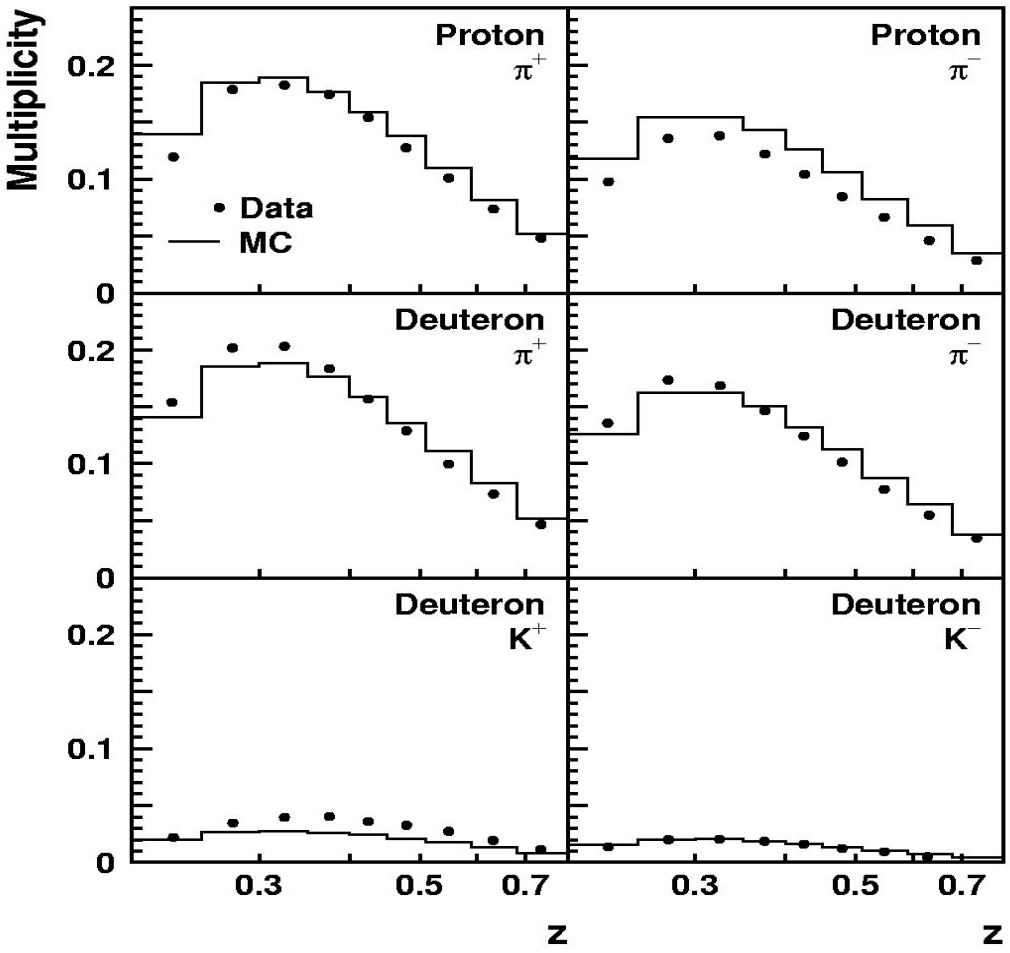
$$A_1^h(x) = \frac{\sum_q e_q^2 \Delta q(x) \int_{0.2}^{0.8} D_q^h(z)\,dz}{\sum_{q'} e_{q'}^2 q'(x) \int_{0.2}^{0.8} D_{q'}^h(z)\,dz} = \sum_q P_q^h(x) \frac{\Delta q(x)}{q(x)}$$

- Published in *Phys. Rev.* D71(2005) 012003.
- Same method as used at SMC (*Phys. Lett.* B420 (1998) 180), but with identified hadrons.
- Purities calculated from LUND model tuned to HERMES hadron multiplicities (LEPTO+JETSET+GEANT)
- Simultaneous fit w.r.t. hadron types and x_{Bj} bins to include smearing effects.

HERMES Kinematics

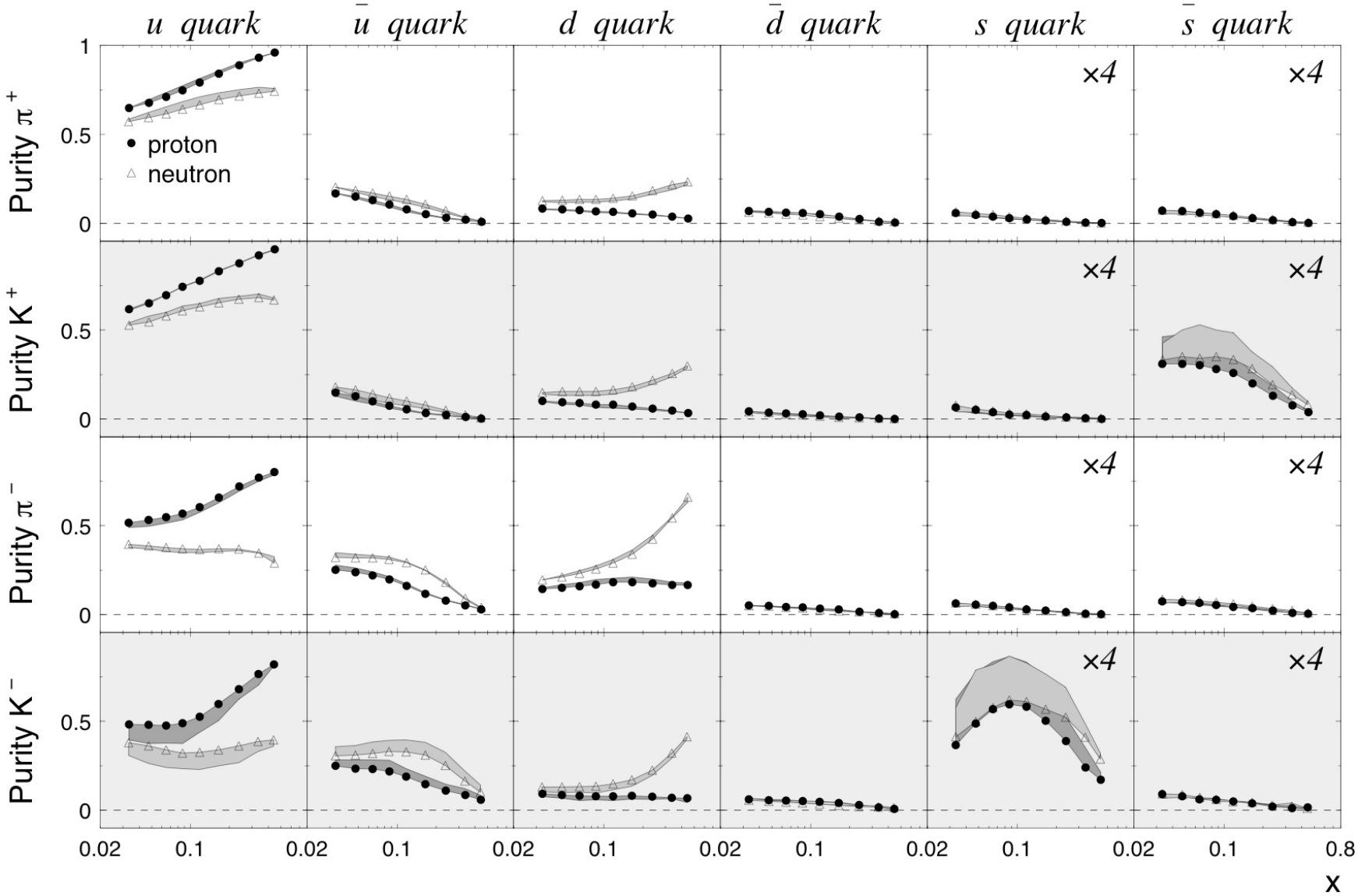
- $E_e = 27.5$ GeV, $P_e = \pm 53\%$
- Longitudinally Polarized H, D, $P_{H,D} \sim 82\%$
- $W^2 > 10$ GeV^2
- $Q^2 > 1.0$ GeV^2
- $y = \nu/E < 0.85$
- $0.2 < z < 0.8$ ($x_F > 0.1$ also)
- Charged pions from H target identified with threshold Č
- Charged pions and kaons from D target identified with RICH

HERMES Multiplicities

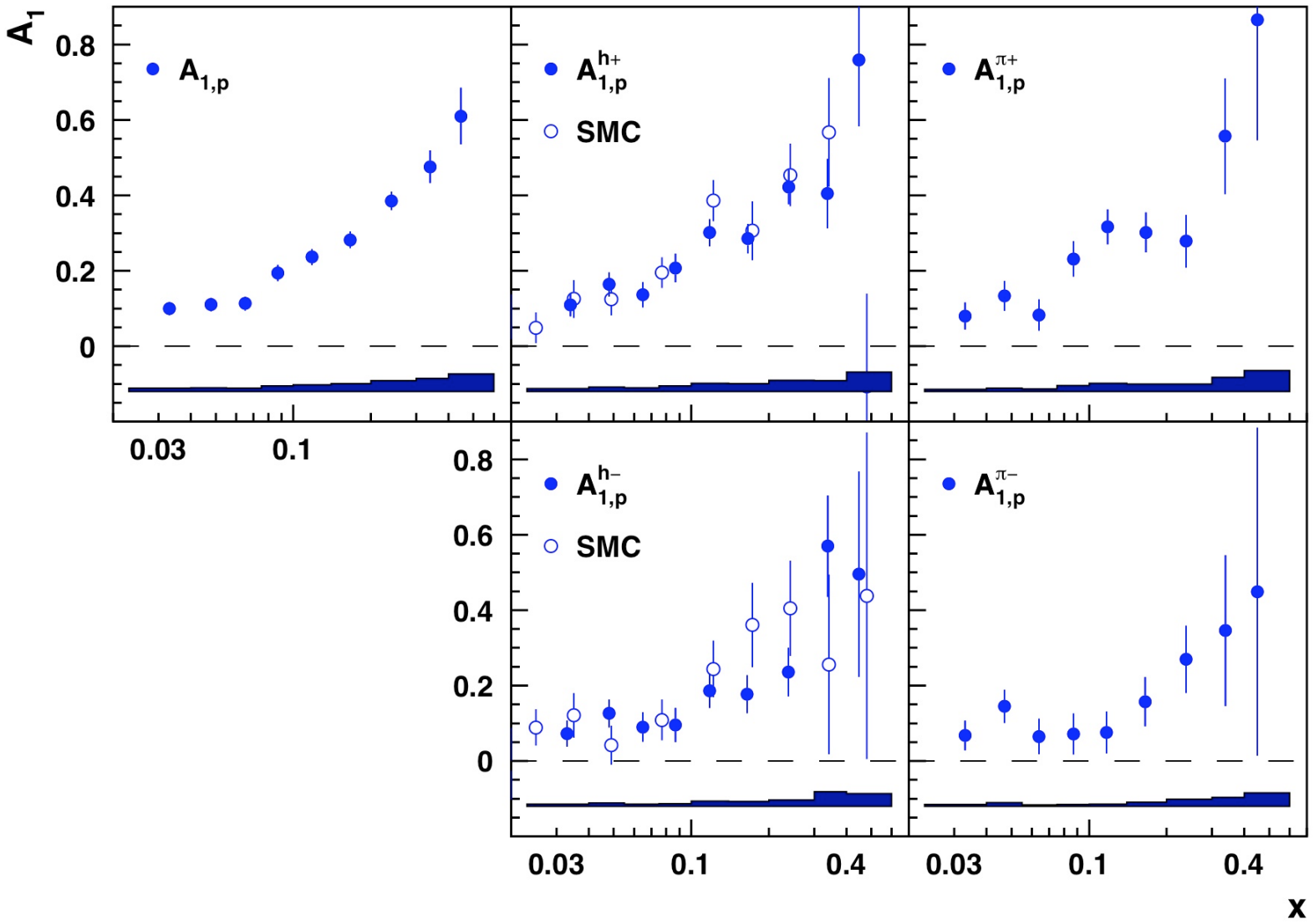


- CTEQ5L unpolarized PDFs
- Fragmentation model (11 JETSET parameters) tuned by minimizing χ^2 of MC simulation compared to unpolarized data.
- Integrated over z in purities

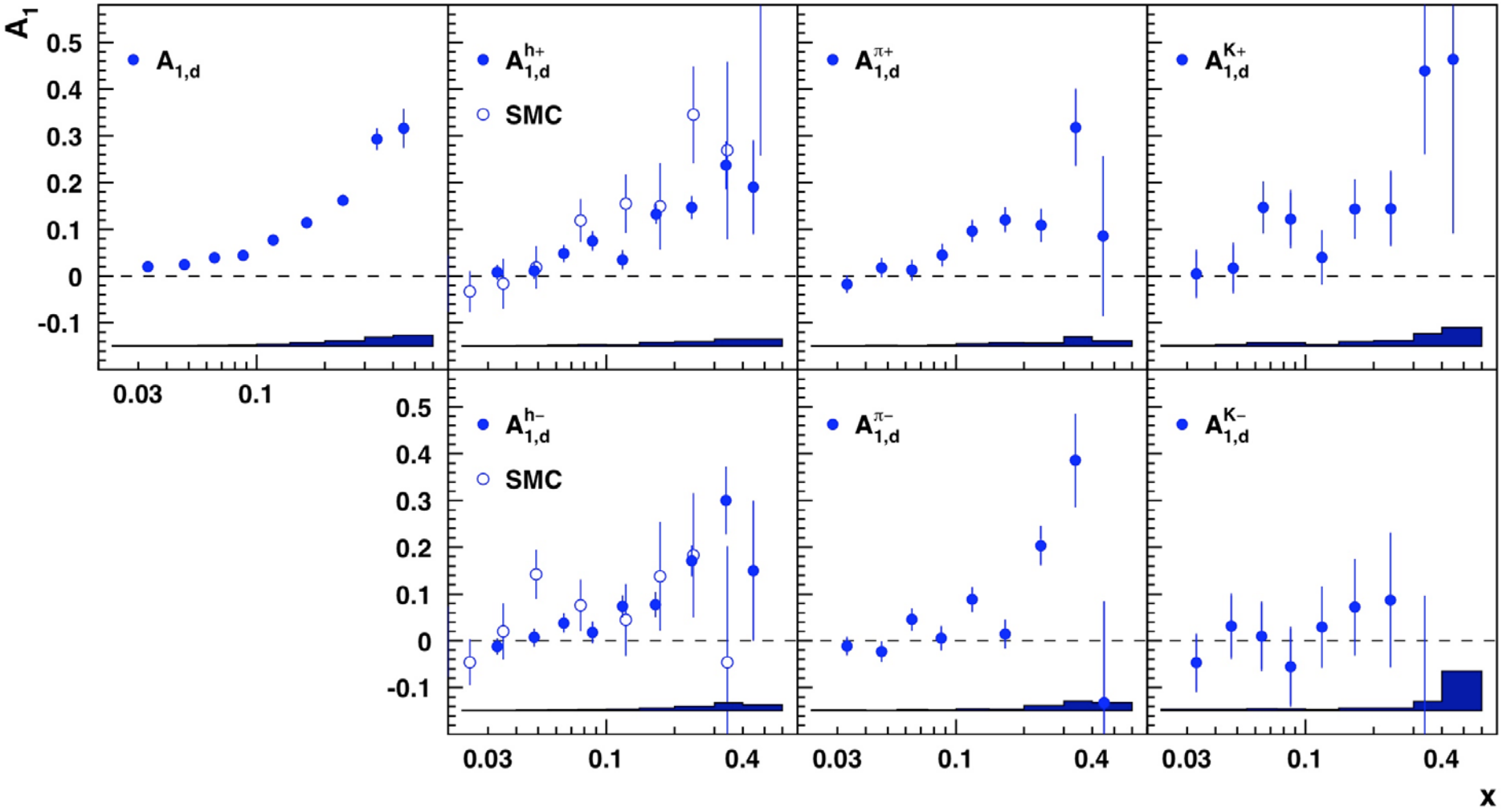
HERMES Purities



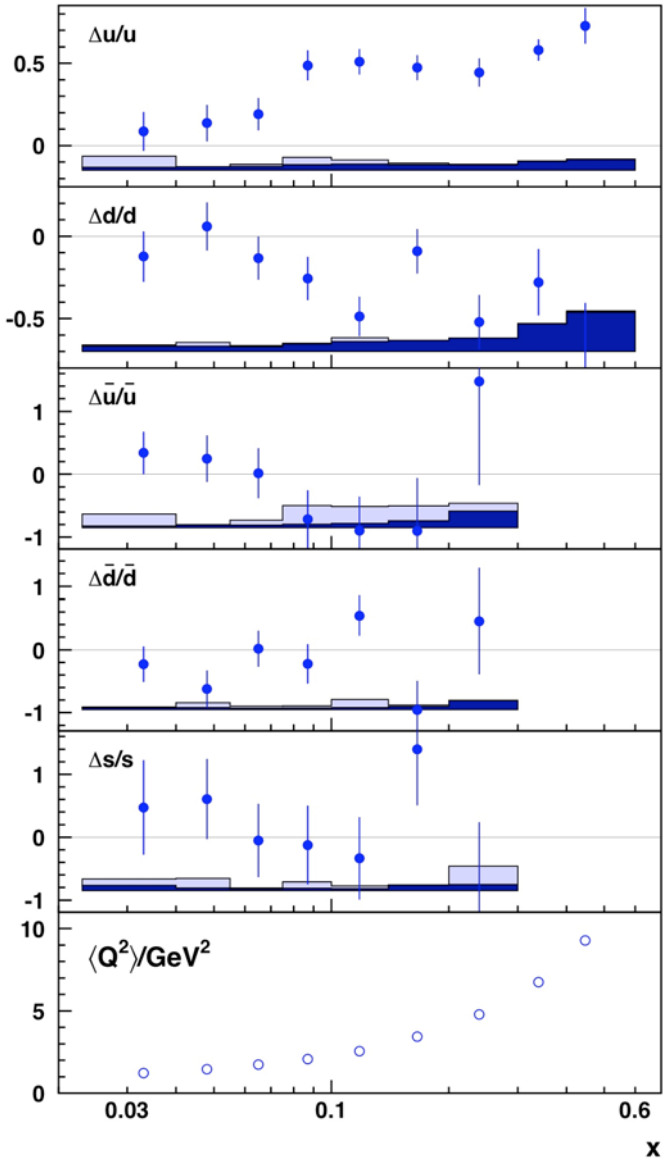
Semi-inclusive Asymmetries from H



Semi-inclusive Asymmetries from D

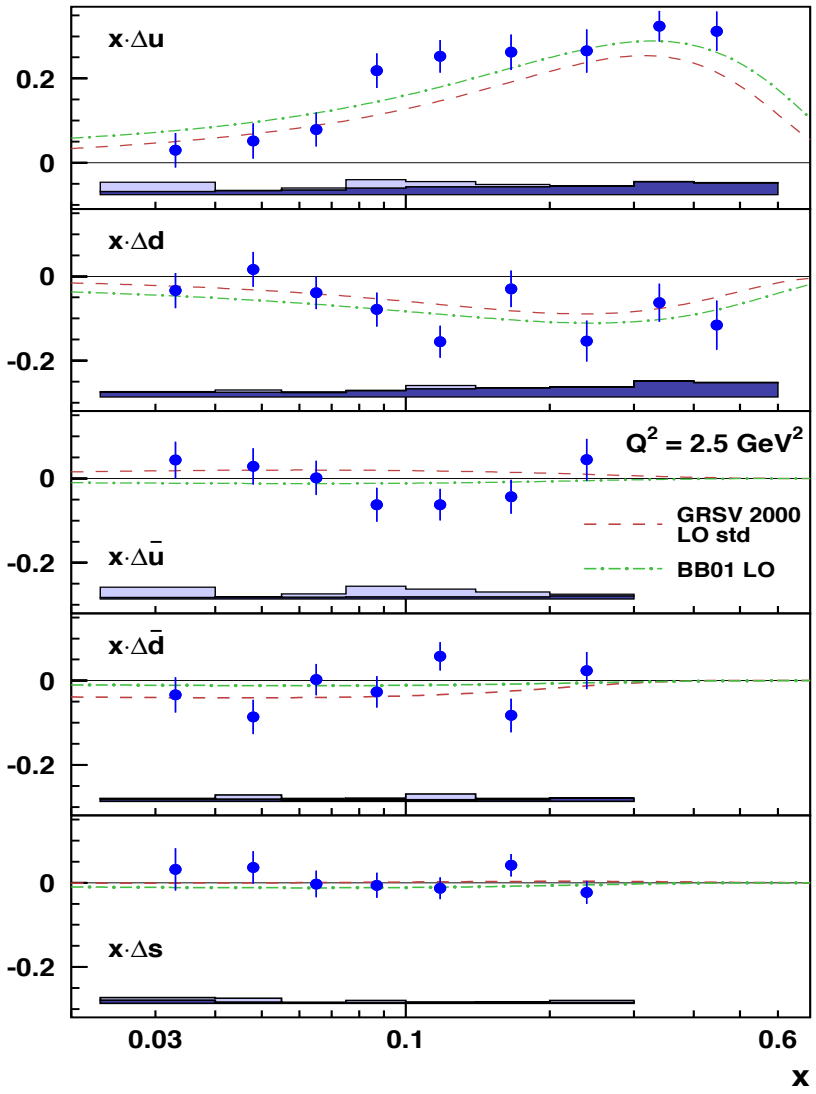


LO Flavor Decomposition: Polarizations



- No sensitivity to $\Delta\bar{s}$, $\Delta\bar{s} \equiv 0$
- All sea polarizations set to zero above $x_{Bj} > 0.3$
- Polarizations assumed independent of Q^2
- Light shaded band: FF uncertainty
- Dark shaded band: Asymmetry systematic uncertainty

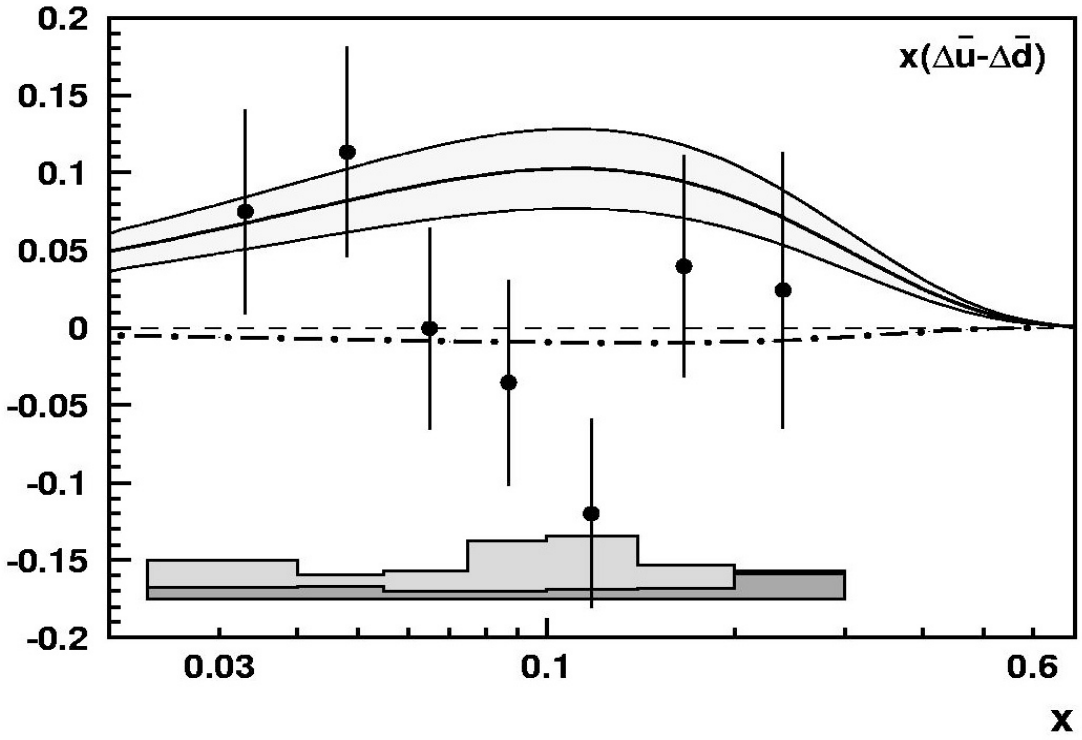
LO Flavor Decomposition: Δq



- "Valence" Δ*u* best determined
- "Valence" Δ*d* less well
- Sea Δ*q's* consistent with zero within large statistical uncertainties
- Δ*s* "favors" positive values but NLO fits to inclusive (e.g. GRSV2000 and BB01) + world semi-inclusive still give small negative value (e.g. de Florian, Navarro, Sassot, *Phys. Rev.* D 71 (2005) 094018).

GRSV2000: *Phys. Rev.* D63 (2001) 094005
BB01: *Nucl. Phys.* B636 (2002) 225

Flavor Asymmetry in the Light Sea



Model Prediction	χ^2/ndf
Meson Cloud Model	8.1/7
Chiral Quark Soliton Model	17.6/7
Symmetric Light Sea	7.7/7

Meson Cloud Model: Cao & Signal, *Phys. Rev.* D 68 (2003) 074002.
Chiral Quark Soliton Model: Dressler *et al.*, *Eur. Phys. J.* C 14 (2007) 147.

LO Isoscalar Extraction of Δs I

Look at isoscalar observables from isoscalar target!

$$\Delta S(x) \equiv \Delta s(x) + \Delta \bar{s}(x)$$

$$\Delta Q(x) \equiv \Delta u(x) + \Delta \bar{u}(x) + \Delta d(x) + \Delta \bar{d}(x)$$

Asymmetries:

$$A_{1,D}(x) = \frac{5\Delta Q(x) + 2\Delta S(x)}{5Q(x) + 2S(x)}$$

$$A_{1,D}^{K^+ + K^-}(x) = \frac{\Delta Q(x)\int D_Q^{K^+ + K^-}(z)dz + \Delta S(x)\int D_S^{K^+ + K^-}(z)dz}{Q(x)\int D_Q^{K^+ + K^-}(z)dz + S(x)\int D_S^{K^+ + K^-}(z)dz}$$

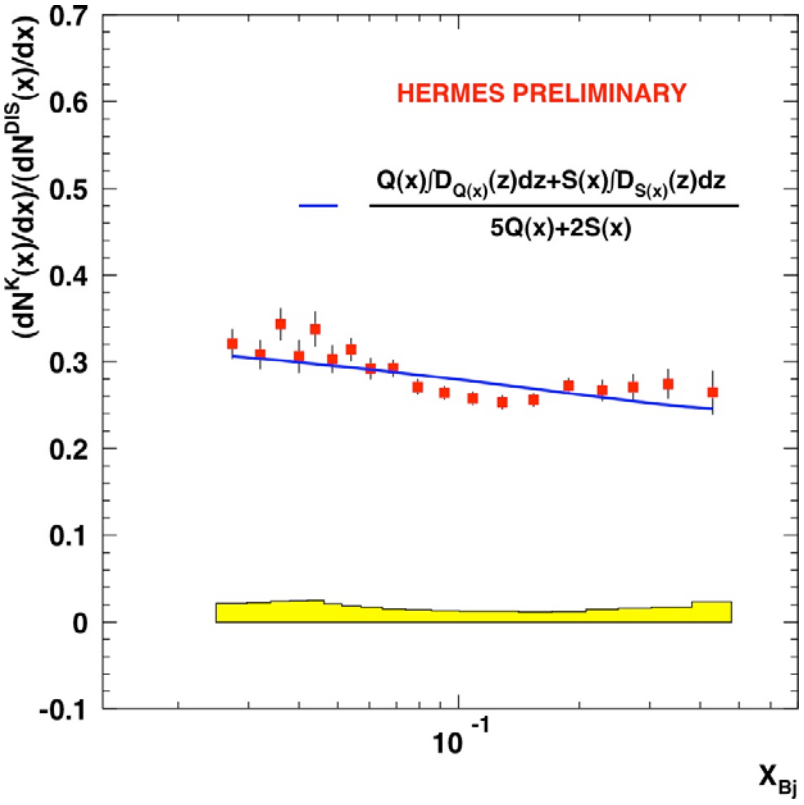
LO Isoscalar Extraction of Δs II

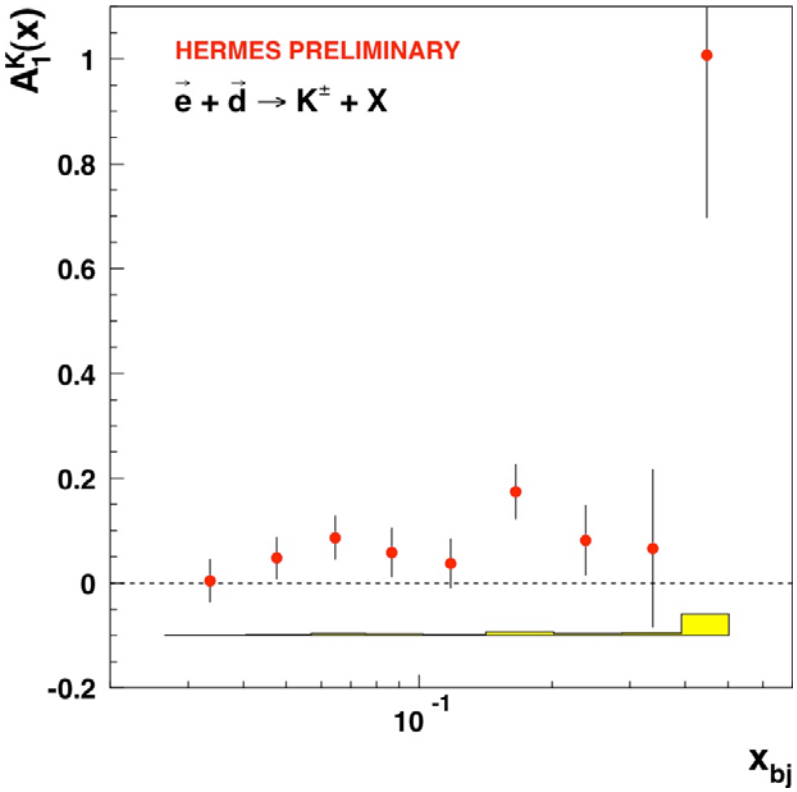
Now use unpolarized PDF(CTEQ6L) + HERMES Multiplicity to determine Q(x), S(x), D^{K+K}:

$$\frac{dN_D^{K^+ + K^-}(x)}{dN_D^{inclusive}(x)} = \frac{\Delta Q(x)\int D_Q^{K^+ + K^-}(z)dz + \Delta S(x)\int D_S^{K^+ + K^-}(z)dz}{5Q(x) + 2S(x)}$$

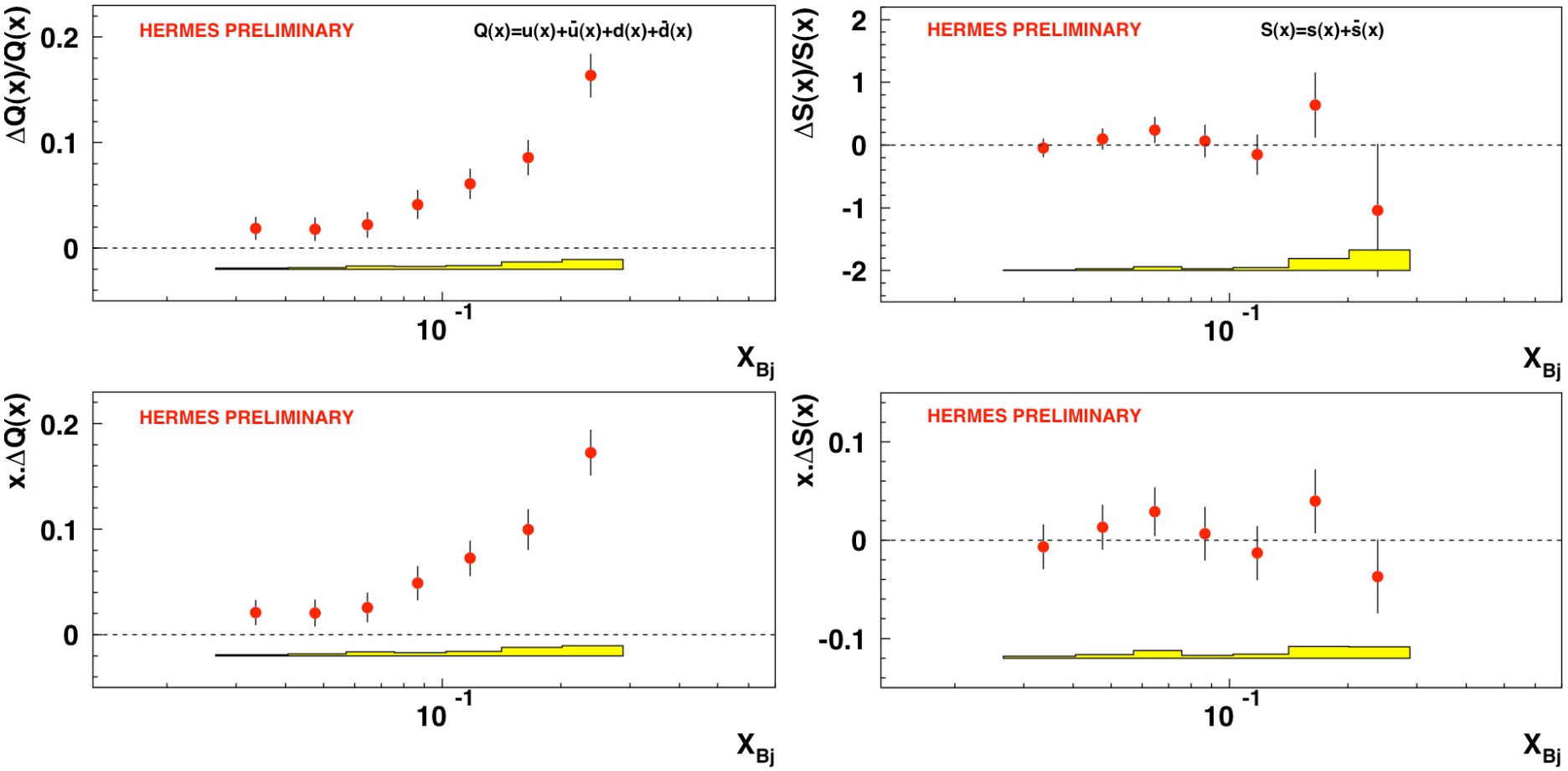
Same kinematics as 5 flavor analysis

Isoscalar Kaon Multiplicity and Asymmetry





Polarizations and Helicity Distributions from Isoscalar Analysis

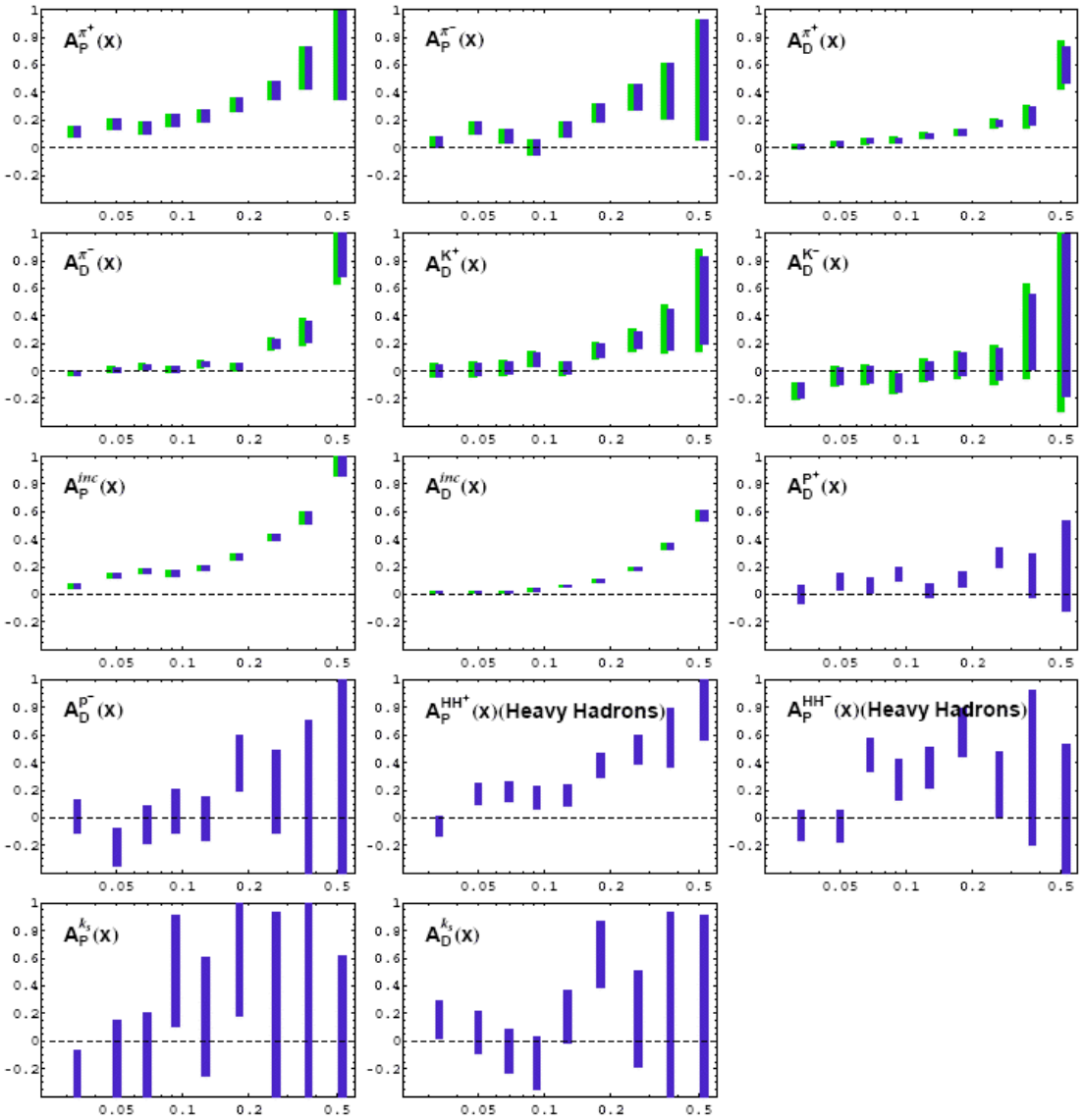


Better determination than 5 flavor, still consistent with zero, but uncertainties are still large relative to (negative) global fit results

Ongoing HERMES Δq Efforts

- Include additional low momentum identified hadrons from the D target (2-4 GeV/c)
- Include additional hadron asymmetries from H and D data
- Bin/fit asymmetries in z, p_T
- More rigorous study of systematic uncertainties from fragmentation modeling.

New Data (MC Study)



- **Published**
- **New**

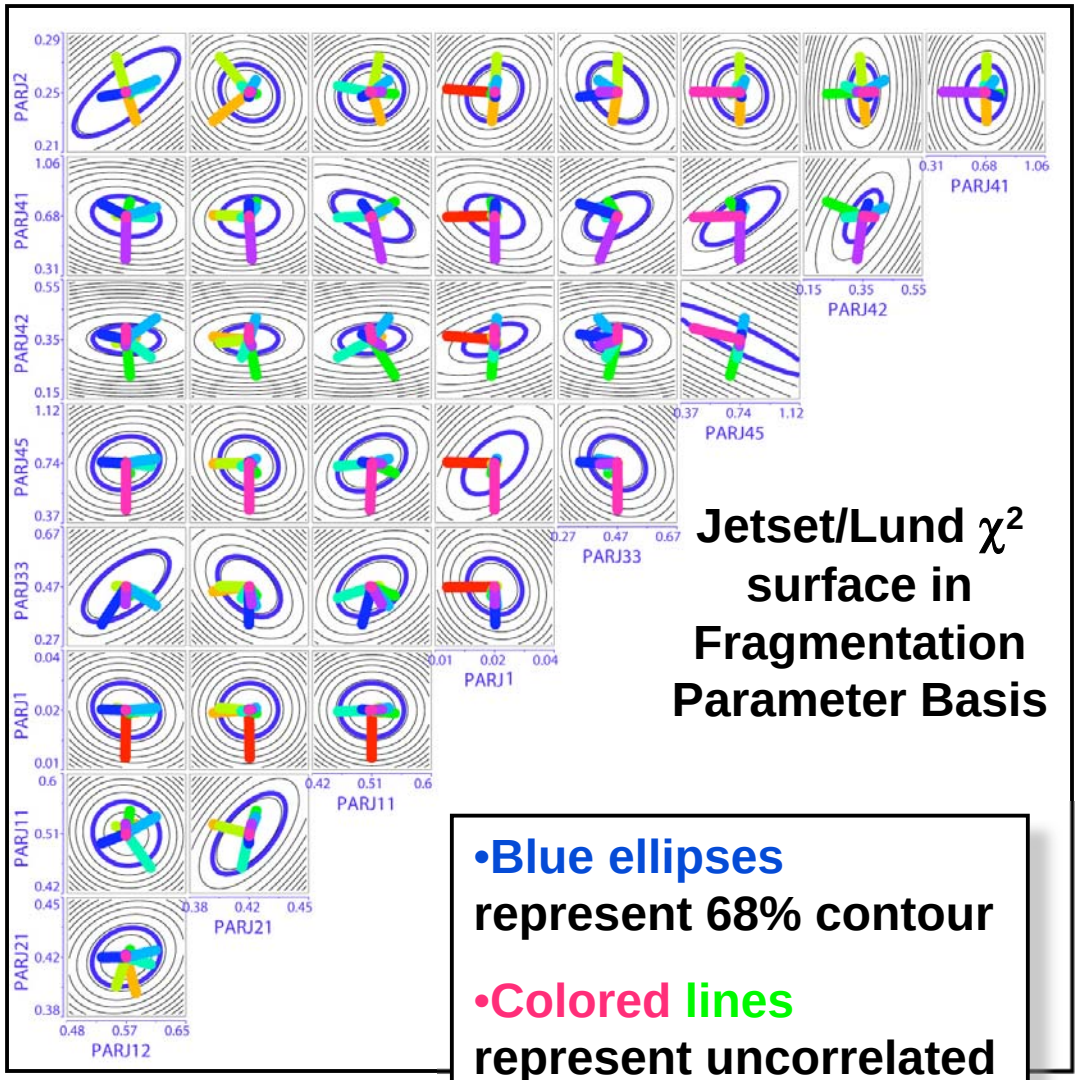
- π^0, K_s,Λ from H,D
- Heavy $h^{+,-}$ from H
- $p^{+,-}$ from D

Correlating MC tune and $\Delta q(x)$ Systematic Uncertainty

Scan the χ^2 surface around the best Monte Carlo tune.

- Correlations are quite clear between parameters
- Generate and diagonalize the matrix of 2nd derivatives to find linear combinations that are uncorrelated

Soon from J. Rubin, UIUC



Jetset/Lund χ^2 surface in Fragmentation Parameter Basis

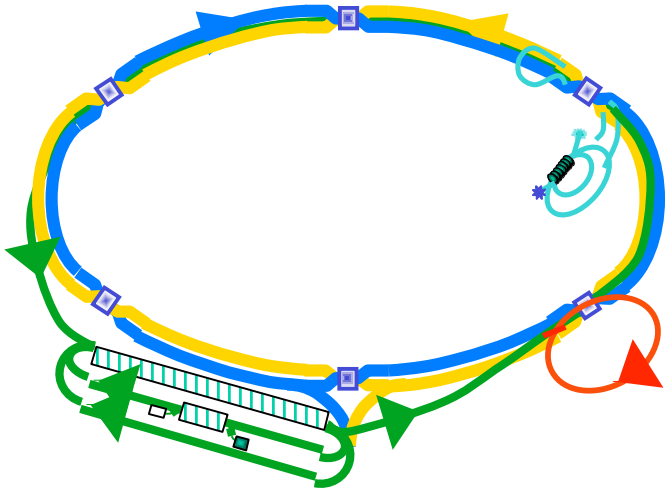
- **Blue ellipses represent 68% contour**
- **Colored lines represent uncorrelated parameter directions**

Conclusions I

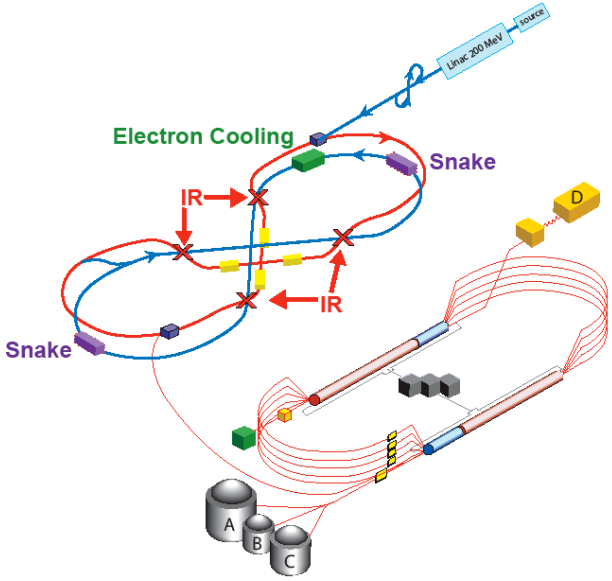
- General features of flavor structure (at mid-range x_{Bj}) is now clear:
  - → Valence distributions “large” but also “small”
  - → Sea distributions consistent with zero and flavor symmetric, but uncertainties still large (statistics limited).
- Although PDF fits at NLO still indicate a negative strange sea, semi-inclusive data seem to favor zero or positive. Too early to say, but this could indicate some interesting physics!
  - → Odd low x behavior?
  - → Odd SU(3) flavor symmetry breaking?
  - → Breakdown of either factorization and/or universality?
- Polarized Light sea flavor asymmetry still poorly determined.

Electron Ion Collider Projections (with J. Seele)

eRHIC@BNL



ELIC@JLab



$<L>_{min}=10^{33}$ cm^{-2}s^{-1}

P ~ 70-80%

CM energy between 20 and 100 GeV

Simulations

The cross sections, correlations, yields, and purities were simulated using LEPTO

An integrated luminosity of 100 days at $10^{33}cm^{-2}s^{-1}$

~8.6 fb^{-1}

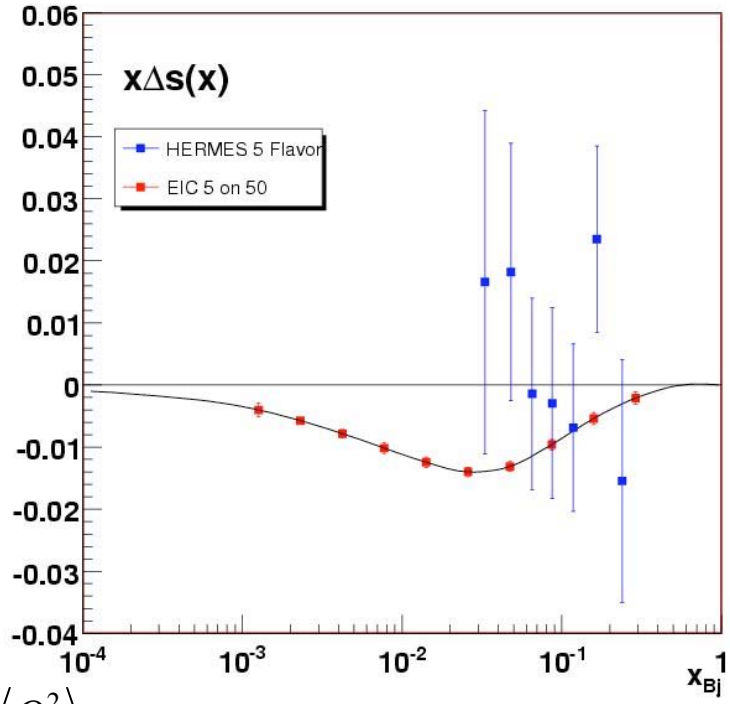
3 proposed energies were simulated
(E_{e-} on E_p) 5 on 50, 7 on 150, and 10 on 250

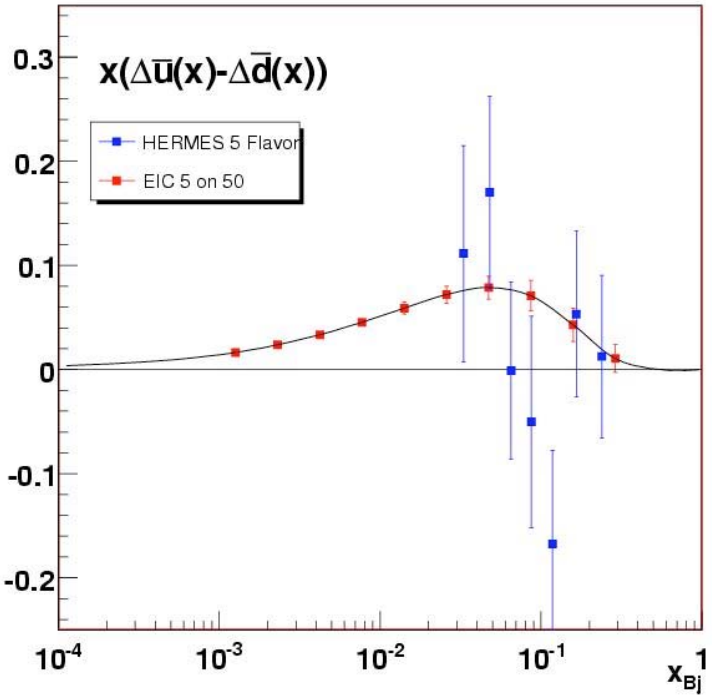
Cuts consistent with DIS and basic detector requirements

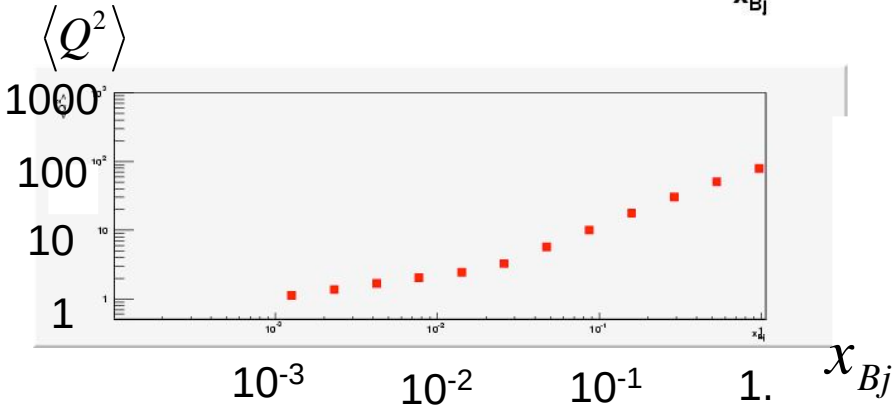
Perfect PID

6 species were used in this study: $\pi^+, \pi^-, K^+, K^-, p, \bar{p}$

5 on 50 Expectations

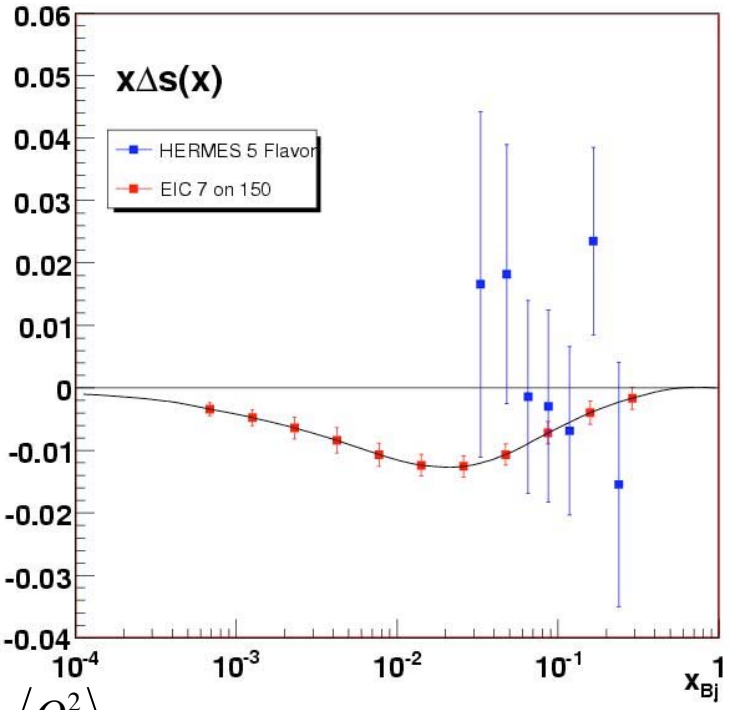


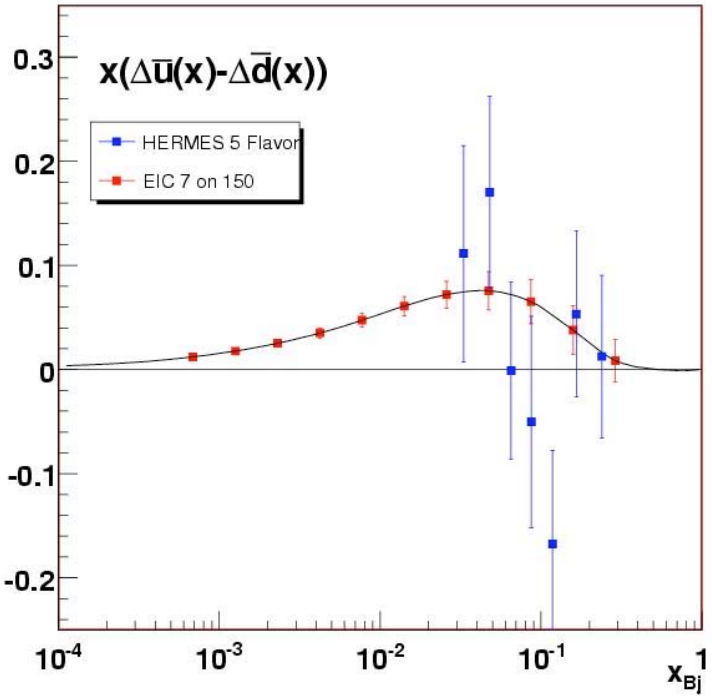


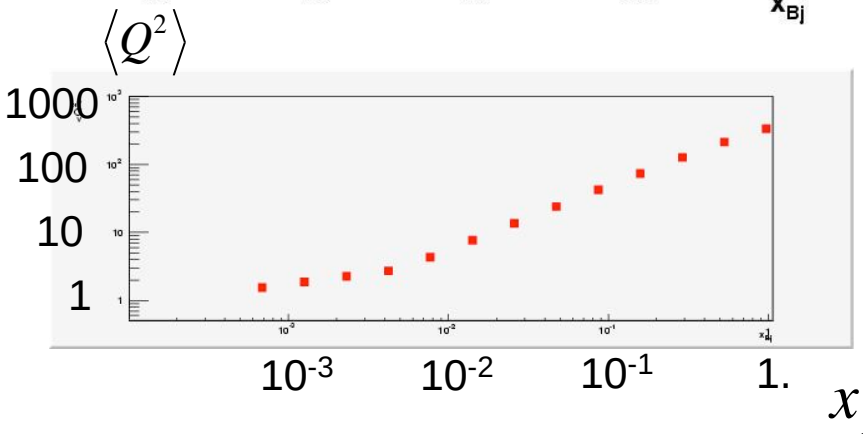


Curves are GRSV2000

7 on 150 Expectations

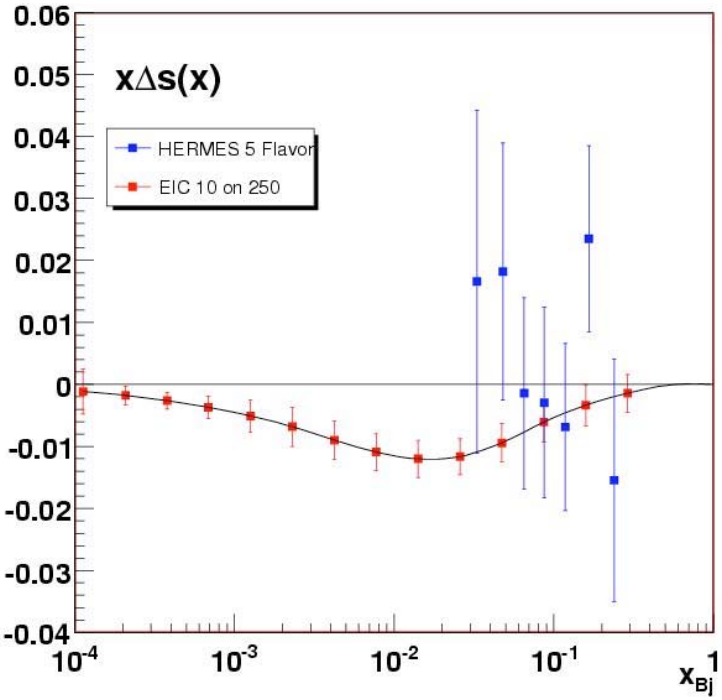


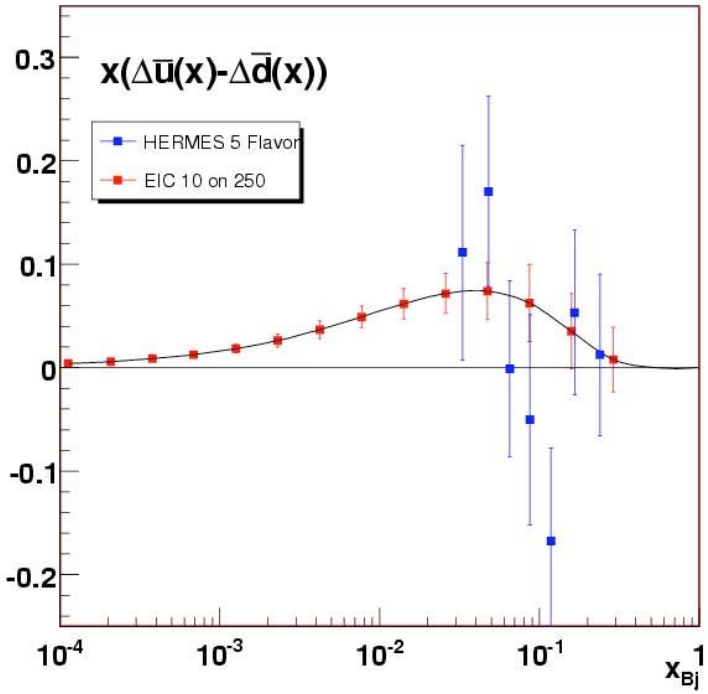


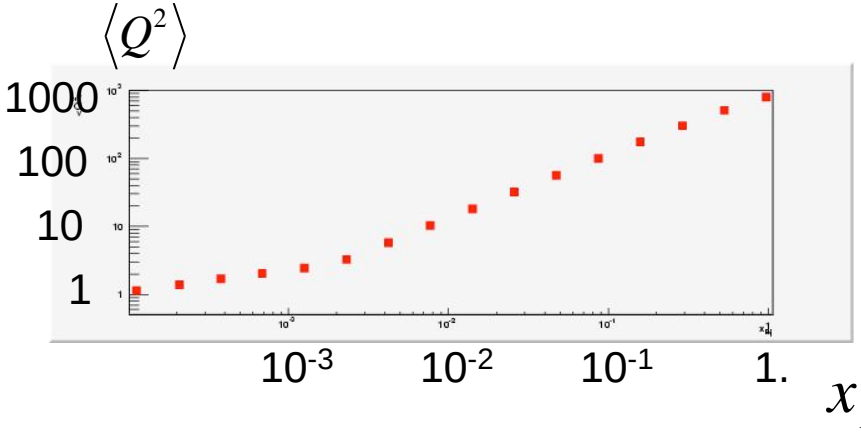


Curves are GRSV2000

10 on 250 Expectations







Curves are GRSV2000

Future/Plans

- Add detector effects/imperfect PID
- Optimize detector vs. cost for this measurement
- Study accuracy needs of fragmentation functions and pdfs
- Radiative corrections
- Do the study at NLO

Comments

- EIC will offer precision testing of sea asymmetries IF we reduce the uncertainty from FF models
- W asymmetries measurements are a vital test of our understanding of fragmentation, in addition to their main goal of the determination of the quark polarizations
- High x will be the domain of JLab